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ORIGINAL RESEARCH

COMPARISON OF THE IMMEDIATE EFFECT OF DIFFERENT TYPES OF TRUNK EXERCISE ON THE STAR EXCURSION BALANCE TEST IN MALE ADOLESCENT SOCCER PLAYERS

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ABSTRACT

Purpose/Background: Trunk exercises, such as trunk stabilization exercises (SE) and conventional trunk exercises (CE), are performed to improve static or dynamic balance. Recently, trunk exercises have also been often used as part of warm-up programs. A few studies have demonstrated the immediate effects of SE and CE on static balance. However, immediate effects on dynamic balance are not yet known. Therefore, the purpose of this study was to compare the immediate effect of SE with that of CE on the Star Excursion Balance Test (SEBT).

Methods: Eleven adolescent male soccer players (17.9 $\pm$ 0.3 years, 168.5 $\pm$ 5.4 cm, and 60.1 $\pm$ 5.1 kg) participated in this study. A crossover design was used, and each participant completed three kinds of testing sessions: SE, CE, and non-exercise (NE). Experiments took place for three weeks with three testing sessions, and a 1-week interval was provided between different conditions. Each testing session consisted of three steps: pretest, intervention, and posttest. To assess dynamic balance, the SEBT score in the anterior, posteromedial, and posterolateral directions was measured before and 5 minutes after each intervention program. The data of reach distance were normalized with the leg length to exclude the influence of the leg length on the analysis.

Results: The SEBT composite score was significantly improved after the SE ($p < 0.05$) but did not change after the CE and NE ($p > 0.05$). Furthermore, in the SE condition, SEBT scores of the posterolateral and posteromedial directions were significantly improved at the posttest, compared with those at the pretest ($p < 0.05$).

Conclusions: This study demonstrated the immediate improvements in the posteromedial and posterolateral directions of the SEBT only after the SE. This result suggests that the SE used in this study is effective in immediately improving dynamic balance.

Levels of Evidence: 3b

Keywords: Core training, dynamic balance, sit-up, stabilization exercise

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INTRODUCTION

The trunk, which is located at the middle of the kinetic chain, is an essential region for coordination during sports performance and for preventing injuries. In the current study, the trunk was defined as the region of the low back and pelvis, and trunk stability was considered as the ability to control the position and motion of the trunk during dynamic loading and movement conditions.[1] Trunk stability is important for the connection of movements between the lower and upper body, as well as the control of body balance and movements.[2,3] In order to obtain optimal trunk stability, coordination, coactivation, and neural control of trunk muscles are needed.[4] Trunk muscles are classified into local and global muscles depending on their anatomical orientation and function.[5] Local muscles, which have more direct or indirect attachments to the lumbar vertebrae, are associated with the segmental stability of the lumbar spine. On the other hand, global muscles attach to the hips and pelvis, and are related to torque production and the transfer of load between the thoracic cage and the pelvis.[5]

Trunk exercises are often performed to improve sports performance and strength, prevent injuries, and rehabilitate patients with low back pain or dysfunction. One type of trunk exercises, described as conventional exercises (CE), include repeated flexion and extension of the trunk, such as sit-ups or back extensions, and are performed to strengthen the trunk muscles.[6] Another type of trunk exercises described as trunk stabilization exercises (SE) keep the lumbar spine in a neutral position and adjust functional postures with minimal accompanying trunk movements, such as the back bridge and side bridge. The main aim of the SE is to restore and improve the coordination and co-contraction of global and local muscles.[7] Previous studies have demonstrated that SE improve trunk stability,[8,9] and athletic performance,[8,10] and prevent low back pain.[9,11,12] Recently, several researchers have demonstrated that SE improve static and dynamic balance.[1,13-15]

SE's are also used as part of warm-up programs, such as the "FIFA 11+" injury prevention program. Previous authors have demonstrated that poor trunk stability and strength are associated with a higher risk of lower extremity injuries.[16,17] Warm-up programs including the SE have been demonstrated to reduce the incidence of lower extremity injuries.[18-21] Bizzini et al[22] have demonstrated that physiological responses, performance, and static and dynamic balance were improved immediately after the FIFA 11+ program. Thus, these factors would be expected to be linked to reducing the incidence of the injuries. However, it is not known how much the SE contribute to improving physiological responses, performance, and static and dynamic balance and preventing injuries because there have been very few studies that investigated the immediate effects of the SE alone. To the authors' knowledge, only two reports about the immediate effects of trunk exercises on static balance have been published.[23,24] Kaji et al[23] reported that the SE program immediately improved static balance. Imai et al.[24] compared the immediate effect of the SE on static balance with that of the CE. They found that static balance improved immediately with SE but did not improve with the CE. This result indicates that the effect of training on static balance varies depending on the types of trunk exercises and that the immediate improvement of static balance is a specific effect of the SE. Imai et al[15] and Kahle et al[13] previously reported that dynamic balance was improved by a 12-week and 6-week SE program, respectively. However, the immediate effect of SE or CE on dynamic balance is not yet known because of the lack of evidence related to the immediate effect of trunk exercises.

Therefore, the purpose of this study was to compare the immediate effect of SE on dynamic balance with that of CE. Dynamic balance is often assessed by using the Star Excursion Balance Test (SEBT), which is a series of single-limb squats in which the subject uses the non-stance limb to maximally reach a touch point along designated lines on the ground.[25] This test is simple and inexpensive, and has demonstrated good test-retest reliability.[26-29] Moreover, the SEBT is useful not only as an assessment of dynamic balance but also a predictive measurement of the risk of lower extremity injuries.[30,31] However, there are no reports about the immediate effect of SE or CE on the SEBT. The authors hypothesized that only the SE program would improve the SEBT immediately.

METHODS

Participants

Eleven adolescent male soccer players participated in this study. Their mean ± SD age, height, and body mass were 17.9 ± 0.3 years, 168.5 ± 5.4 cm, and 60.1 ± 5.1 kg, respectively. All participants were members of the same high school soccer club and had been attending soccer practice or games six times per week at the time of the investigation. Players who reported low back pain or a history of lower extremity injuries that required treatment or that might have inhibited performance within the last 12 months were excluded. All players and their parents provided written informed consent before participation. This study was reviewed and approved by the Ethical Committee at the University of Tsukuba, and carried out in accordance with the Declaration of Helsinki.

Procedures

In this study, a crossover design was used and each participant participated in testing with three conditions, which were SE, CE, and non-exercise control (NE), in order to compare the influence of two types of trunk exercises on performance on the SEBT. The research project took place over a period of three weeks with three testing sessions. A 1-week interval was provided between the different conditions to rule out the influence of the previous exercises performed.

Each testing session consisted of three steps: pretest, intervention, and posttest. The measurements of the SEBT were performed before and five minutes after the training period. The SE and CE programs took five minutes and were directed and supervised by the researcher. In the NE condition, participants sat and rested on a chair for 5 minutes.

The order in which participants performed the exercises of the three conditions was decided by the researcher to minimize the "learning effects", a term used here to suggest the degree of the participants' familiarity with the three kinds of exercises, which is most likely determined by the order of the exercises. Consequently, four participants performed exercises in the order SE, CE, and NE; four participants in the order CE, NE, and SE; and three participants in the order NE, SE, and CE.

The Star Excursion Balance Test

The participants performed the SEBT in the anterior, posteromedial, and posterolateral directions.[29,32-34] They received verbal instruction and visual demonstration of the SEBT from the same examiner before performing the test.

The participants stood on the leg they used for kicking a ball, with the most distal part of the great toe placed on the center of the grid. While maintaining a single-leg stance, they used the opposite leg to reach, as far as possible toward the end of the line along a grid in the anterior, posteromedial, and posterolateral directions. Then, they touched the ground lightly with the most distal part of the reaching foot before returning to the starting position. Their hands were held at the iliac crest during the test. All tests were performed barefoot to rule out the influences of shoes. After six practice trials were completed, the participants rested for two minutes and then performed three test trials in each direction.[35] The order of the reaching directions was randomized at each test session. The test was discarded and then repeated in the same manner if a participant failed to maintain the unilateral stance, lifted or moved the standing foot from the grid, or failed to return the reaching foot to the starting position.

The longest reach distance in each direction was used for the analysis. For an accurate analysis, the data of reach distance was normalized with the leg length to exclude the influence of leg length.[25,36] The leg length was measured with a tape measure from the anterior superior iliac spine to the center of the ipsilateral medial malleolus.[36] The composite score was calculated according to the formula {(sum of all three directions)/(limb length*3)}*100.[29]

Trunk stabilization exercise program

The SE program consisted of the front plank, quadruped exercise, and back bridge (Figure 1). Okubo et al[37] reported that the SE used in this study involve higher activities of local muscles than other exercises. For the front plank, participants maintained a prone position in which the body weight was supported by the toes and forearms. From this position, they raised the right arm and left leg simultaneously and held them straight up for five seconds. Next, they raised the left arm and right leg simultaneously and held them straight up for five seconds. Then, participants lowered their bodies on the floor and rested for 10 seconds. This routine was repeated five times. For

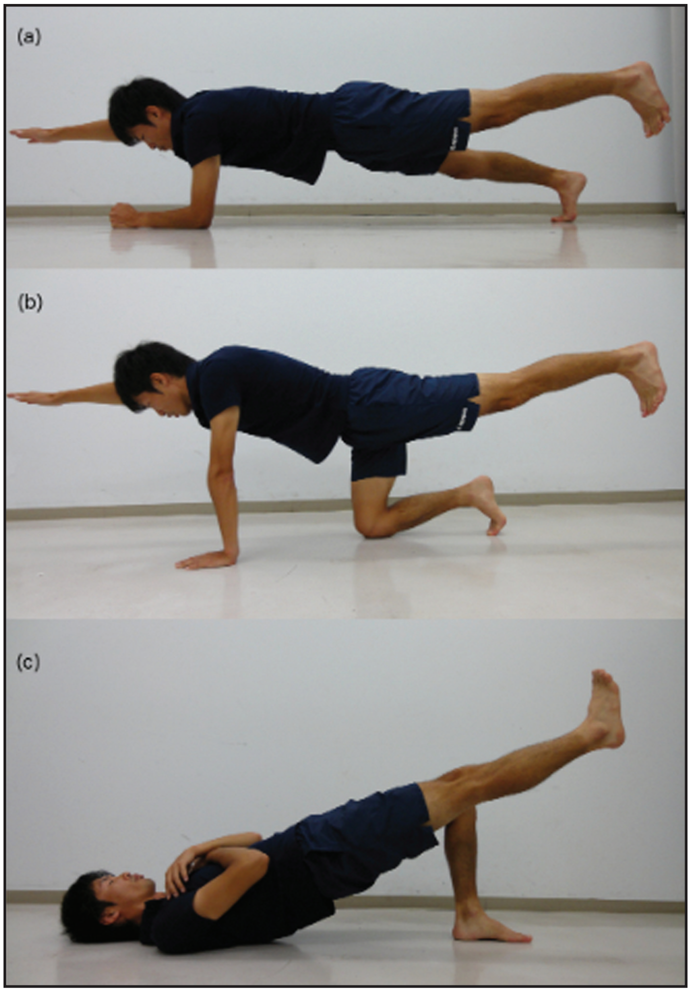

Figure 1. *Trunk stabilization exercise program for this study: (a) the front plank, (b) the quadruped exercise, and (c) the back bridge.*

the quadruped exercise, participants assumed a quadruped position. They were then asked to hold a neutral pelvis position and to breathe normally. Then, they raised their right arm and left leg simultaneously and held them straight up for five seconds. Next, they raised their left arm and right leg simultaneously and held them straight up for five seconds. Then, they rested for 10 seconds. This routine was repeated five times. For the back bridge, participants laid supine on the floor, with their feet flat on the ground, knees bent at 90°, toes facing forward and hands folded across the chest. They raised their pelvis to achieve and maintain a neutral hip flexion angle, then raised one leg from the floor and extended the knee straight. This position was maintained for five seconds. Then, they raised the opposite leg and maintained the position for five seconds. Then, they rested for 10 seconds. This routine was repeated five times.

Conventional exercise program

For the CE program, participants performed sit-ups, sit-ups with trunk rotation, and back extensions (Figure 2). For the sit–ups, participants laid supine in the standard sit-up position, knees bent at 90°, and hands folded across the chest with each hand placed on the opposite shoulder. They were asked to bend and raise the upper body until their elbows reached their thigh and then to return to the starting position. This routine was performed 30 times. For the sit-ups with trunk rotation, participants were asked to raise, bend, and rotate the upper body to the left or right until the elbow touched the opposite thigh from the starting position of the sit-up. This was performed 30 times, alternating on the right and left sides. For the

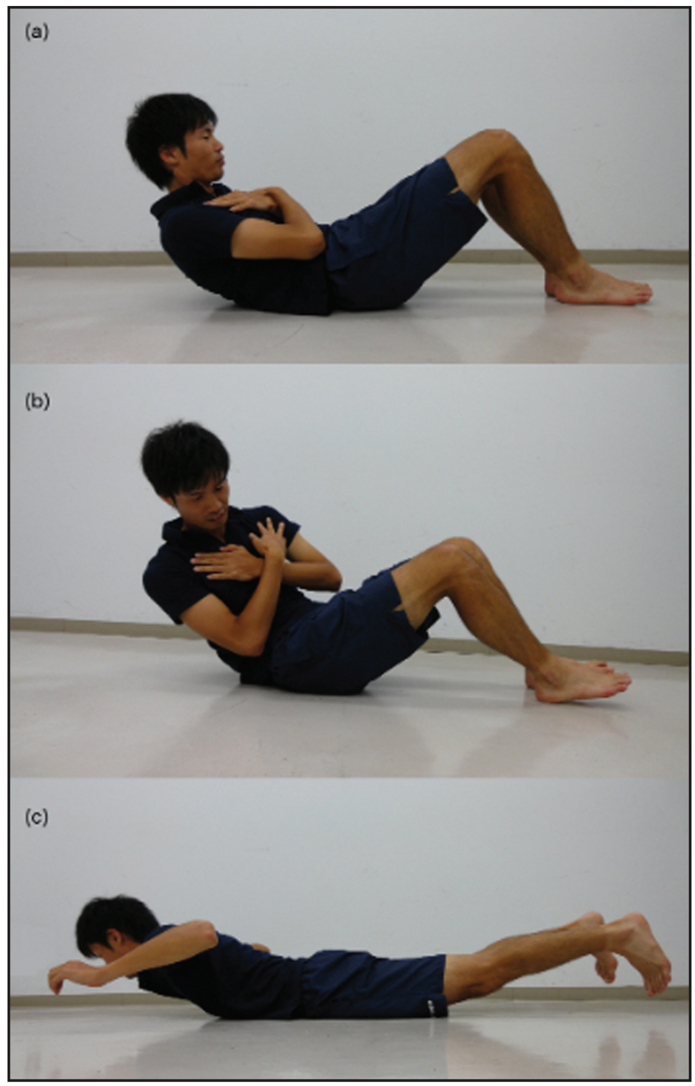

Figure 2. *Conventional exercise program for this study: (a) the sit-up, (b) the sit-up with trunk rotation, and (c) the back extension.*

Table 1. *The results of normalized composite score of the Star Excursion Balance Test*

	Pre*	Post*	Bonferroni	% change	ES
Composite †					
SE	94.0 ± 4.8	96.8 ± 5.7‡	0.000	2.9	0.53
CE	94.7 ± 6.1	95.6 ± 6.5	0.097	1.0	0.15
NE	95.1 ± 5.1	95.4 ± 5.1	0.570	0.3	0.06

*Mean ± SD %
†Significant group-by-time interaction ($p < 0.05$)
‡Significant difference between the pre and post ($p < 0.05$)
CE, Conventional trunk exercises; ES, Effect size; NE, non-exercise control; SE, Trunk stabilization exercises.

back extension, the participants lifted their upper body and legs off the floor simultaneously from a prone position on the floor. After a comfortable elevation, they lowered their upper body and legs to return to the starting prone position. These movements were repeated 50 times.

Statistical analysis

Statistical analyses were performed by using the software SPSS for Mac ver. 19 (SPSS Inc. Chicago, IL, USA). The test-retest reliability for the SEBT was calculated by using a two-way random effect model intraclass correlation coefficients (ICCs). The normality and equal variance assumptions were checked by using the Kolmogorov-Smirnov test and Levene test, respectively. The baseline data of the SEBT between groups were compared by using a one-way ANOVA. A two-way (group × time) repeated-measures ANOVA with a mixed-model design was used to assess the changes over time and the between-group difference. When a statistically significant interaction effect was found, a Bonferroni post hoc test was done. Statistical significance was inferred at $p < 0.05$. Effect sizes (ESs) were calculated by using Cohen's d to compare the results of the pre-test and the post-test. ESs were interpreted as small (0.21–0.50), medium (0.51–0.80), or large (>0.81).

RESULTS

The test-retest reliability analysis demonstrated ICCs of 0.965, 0.888, and 0.948 for the anterior, posterolateral, and posteromedial directions, respectively.

There were no significant differences between groups at the baseline data of each direction ($p > 0.05$). For the SEBT composite score, significant condition-by-time interactions existed ($F = 5.441$, $p = 0.010$). A Bonferroni post hoc test detected that the SEBT composite score was increased significantly only after the SE ($p < 0.001$, ES = 0.53). A moderate ES (0.53) was associated with this relation. The composite score did not change after the CE ($p = 0.097$, ES = 0.15) and NE ($p = 0.570$, ES = 0.06) (Table 1).

In the analysis of each direction, there were significant condition-by-time interactions in the posterolateral direction ($F = 5.764$, $p = 0.008$) and posteromedial direction ($F = 7.745$, $p = 0.002$). However, no interaction effect in the anterior direction was noted ($F = 0.116$, $p = 0.891$). In the SE condition, the Bonferroni post hoc test revealed that the SEBT score of the posterolateral direction ($p = 0.002$, ES = 0.44) and posteromedial direction ($p < 0.001$, ES = 0.74) was significantly greater at the posttest than at the pretest (Table 2). Small to moderate ESs were associated with these relations.

DISCUSSION

This study compared the immediate effects of different types of trunk exercises on the performance on the SEBT. One interesting finding was that the SEBT composite score significantly improved only after the SE but not after the CE and NE. Thus, the results indicate that the SE has the immediate effects concerning improvement of dynamic balance. Although previous studies have demonstrated that 12 weeks and 6 weeks of the SE improved dynamic balance,[13,15] the current research provides the first evidence showing the immediate effects of the SE on dynamic balance.

Table 2. *The results of normalized reach distance scores of each direction of the Star Excursion Balance Test*

Direction	Pre*	Post*	Bonferroni	% change	ES
Anterior					
SE	74.0 ± 3.4	73.7 ± 4.6	-	-0.4	0.07
CE	75.0 ± 6.0	74.9 ± 5.1	-	0.1	0.01
NE	73.3 ± 5.3	73.5 ± 4.8	-	0.3	0.04
Posterolateral †					
SE	102.8 ± 7.3	106.2 ± 8.1‡	0.002	3.3	0.44
CE	103.6 ± 6.8	105.2 ± 8.1	0.115	1.5	0.21
NE	105.4 ± 7.4	104.1 ± 7.8	0.191	-1.3	0.17
Posteromedial †					
SE	105.3 ± 5.8	109.8 ± 6.4‡	0.000	4.3	0.74
CE	105.5 ± 7.6	106.2 ± 8.2	0.403	0.6	0.08
NE	106.6 ± 4.9	108.0 ± 4.4	0.077	1.3	0.29

*Mean ± SD %

†Significant group-by-time interaction ($p < 0.05$)

‡Significant difference between the pre and post ($p < 0.05$)

CE, Conventional trunk exercises; ES, Effect size; NE, non-exercise control; SE, Trunk stabilization exercises.

Concerning the reach direction, results show that the reach distance improved in the posteromedial and posterolateral directions and that in the anterior direction did not change. For the posterior directions, the hip flexion range of motion of the stance leg is important.[38] Because the trunk is leaning forward to maintain balance in the SEBT position,[39] eccentric muscle contraction of the hamstrings and low back muscles, such as the erector spinae and multifidus, is needed.[40] Thus, the function of the local muscles as monitors and the control of the trunk motion by the global muscles are both important. During the SE program prescribed here, the trunk position was maintained and adjusted by working the local and global muscles.[37] Therefore, participants might have improved the control of the trunk position during the posterior directions of the SEBT after the SE. The SE involving arm and leg lifts used in this study have previously been shown to involve high external oblique activity, which is likely to assist in control of trunk rotation.[37] Thus, the improvement in the control of the trunk rotation may help the control of the lower extremity during the posteromedial direction of the SEBT.

In contrast, the anterior direction was not changed significantly. This supported the findings of the previous study that investigated the effect over 8 weeks of training.[29] Hock et al[32] reported that the range of motion of the dorsiflexion influenced the anterior direction to a greater degree than posterior directions. Therefore, it is possible that the anterior direction is more sensitive to changes affected by the distal contributions.

Although the SE program was effective in improving the SEBT, no change was found after the CE program. The SE differs from the CE in terms of the stresses applied on particular body segments. Some basic principles of physical training must be followed to obtain the optimal effects of physical training.[41] The specific adaptation to imposed demands (SAID) is one such basic principle. The SAID principle states that the human body will adapt specifically in response to the demands and stresses placed on it.[41] The SE program consists of closed kinetic chain positions that place unilateral stresses on the hip extensors, and the task of movement is to maintain and control these positions. This stress resembles the stress of the SEBT in the posteromedial and posterolateral directions. On the other hand, the CE applies stress to the lumbar spine flexors and extensors in a dynamic bilateral manner. Therefore, the SE may be more suitable than the CE in terms of SAID as a training program to improve dynamic balance.

Limitations

Several limitations of this study should be considered. First, the sample size was small and the participants were all adolescent male soccer players. Thus, further confirmation of these results must be done in larger and more diverse populations, including female athletes and older individuals. Second, this study investigated the effect on the SEBT of the SE and CE programs comprising three exercises. Various trunk exercises and methods have been utilized to enhance trunk control and the strength of trunk muscles. The results of this study apply only to the SE program used here. Third, this study could not show how long the immediate effect on the SEBT lasts. This problem will need to be investigated in the future to clarify the efficacy of a warm-up program. Moreover, future studies that investigate whether the SE reduce the risk of injuries are needed. Previous studies have demonstrated that the FIFA 11+ program improved the SEBT immediately and that soccer players who adhered to the FIFA 11+ program showed improvement in the SEBT and a reduced injury risk.[21,22] Thus, the SE program that has been demonstrated to cause immediate improvement of the SEBT may have the benefit of resulting in injury prevention.

Practical application

This study demonstrated that the SE improves dynamic balance. The previous study has shown that the SE program used in this study improves static balance.[24] These results suggest that the SE is effective for immediately improving static and dynamic balance. For warm-up exercises, coaches and trainers use many kinds of exercises to improve performance and prevent injuries in athletes. The SE program used in this study is simple and easy to incorporate into a warm-up routine. Moreover, because an immediate effect on SEBT was demonstrated, the SE may enhance athletes' dynamic balance, which is required for almost all athletic activities. Therefore, the authors' would recommend that coaches consider changing their warm-up program to include at least the selected SE exercises, with the hope of enhancing the athlete's dynamic balance.

CONCLUSION

This study demonstrated that the posteromedial and posterolateral directions of the SEBT were improved immediately after the SE, but not after the CE. Results of this study suggest that the SE program used in this study is effective in immediately improving dynamic balance.

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